## CLAIMS

We claim:

1. A light source for use in an opacity monitor for measuring the opacity of gases in an open path of gases, said light source reducing the variation in light intensity across a beam of light projected therefrom.

2. The light source of Claim 1 comprising:

a plurality of light emitting diodes (LEDs) arranged at a predetermined angular orientation with respect to each other and emitting respective light beams therefrom; and

an optical diffuser positioned at a predetermined distance from said plurality of LEDs for mixing and reflecting said respective light beams to form said beam of light having a reduced variation in light intensity.

3. The light source of Claim 2 wherein said plurality of LEDs comprises three LEDs.

4. The light source of Claim 3 wherein said predetermined angular orientation comprises arranging said LEDs to be oriented 120° with respect to each other.

5. The light source of Claim 4 wherein each of said LEDs comprises a pair of leads and wherein said light source further comprises:

an LED holder having three holes positioned 120° with respect to each other;

a clamp member having holes for each one of said leads; and

wherein said LED holder and said clamp member couple together to maintain said LEDs in said predetermined angular orientation.

6. The light source of Claim 5 wherein each of said LEDs comprises a flattened portion and wherein said clamp member is arranged to orient the flattened portion of each of said LEDs towards each other.

7. The light source of Claim 5 wherein each of said LEDs comprises a flange and wherein said optical diffuser comprises an inside surface, said predetermined distance comprising 12.5 mm between said LED flanges and said inside surface.

8. The light source of Claim 1 wherein said optical diffuser is supported inside a diffuser holder, said diffuser holder comprising a low-magnesium aluminum alloy.

9. The light source of Claim 8 wherein said optical diffuser is supported by inside surfaces of said diffuser holder, said inside surfaces being fine machined to provide increased light output from said light beams.

10. The light source of Claim 8 further comprising a glare shield coupled to said diffuser holder.

11. A light source adapted for use in open path gas monitoring, said light source generating a homogeneous light beam.

12. The light source of Claim 11 comprising:

a plurality of light emitting diodes (LEDs) arranged at a predetermined angular orientation with respect to each other and emitting respective light beams therefrom; and

an optical diffuser positioned at a predetermined distance from said plurality of LEDs for mixing and reflecting said respective light beams to form said homogeneous light beam.

13. The light source of Claim 12 wherein said plurality of LEDs comprises three LEDs.

14. The light source of Claim 13 wherein said predetermined angular orientation comprises arranging said LEDs to be oriented 120° with respect to each other.

15. The light source of Claim 14 wherein each of said LEDs comprises a pair of leads and wherein said light source further comprises:

an LED holder having three holes positioned 120° with respect to each other;

a clamp member having holes for each one of said leads; and

wherein said LED holder and said clamp member couple together to maintain said LEDs in said predetermined angular orientation.

16. The light source of Claim 15 wherein each of said LEDs comprises a flattened portion and wherein said clamp member is arranged to orient the flattened portion of each of said LEDs towards each other.

17. The light source of Claim 15 wherein each of said LEDs comprises a flange and wherein said optical diffuser comprises an inside surface, said predetermined distance comprising 12.5 mm between said LED flanges and said inside surface.

18. The light source of Claim 12 wherein said optical diffuser is supported inside a diffuser holder, said diffuser holder comprising a low-magnesium aluminum alloy.

19. The light source of Claim 18 wherein said optical diffuser is supported by inside surfaces of said diffuser holder, said inside surfaces being fine machined to provide increased light output from said light beams.

20. The light source of Claim 16 further comprising a glare shield coupled to said diffuser holder.

21. An opacity monitor for measuring the opacity of gases in an open path of gases, said opacity being defined as the fraction of transmitted light which is lost in transmission through the open path of gases, said opacity monitor comprising:

an optical transmitter for projecting a light beam across the open path of gases using a light source that reduces the variation in light intensity across said projected beam;

a reflector for reflecting a portion of said projected light beam back towards said optical transmitter through said open path gas of gases;

an analyzer for detecting said portion of said projected light beam and calculating the opacity of said gases; and

wherein said optical monitor detects opacities less than 10 percent while operating within specific performance requirements.

22. The opacity monitor of Claim 21 wherein said light source comprises:

a plurality of light emitting diodes (LEDs) arranged at a predetermined angular orientation with respect to each other and emitting respective light beams therefrom; and

an optical diffuser positioned at a predetermined distance from said plurality of LEDs for mixing and reflecting said respective light beams to form said beam of light having a reduced variation in light intensity.

23. The light source of Claim 22 wherein said plurality of LEDs comprises three LEDs.

24. The opacity monitor of Claim 23 wherein said predetermined angular orientation comprises arranging said LEDs to be oriented 120° with respect to each other.

25. The light source of Claim 24 wherein each of said LEDs comprises a pair of leads and wherein said light source further comprises:

an LED holder having three holes positioned 120° with respect to each other;

a clamp member having holes for each one of said leads; and

wherein said LED holder and said clamp member couple together to maintain said LEDs in said predetermined angular orientation.

26. The light source of Claim 25 wherein each of said LEDs comprises a flattened portion and wherein said clamp member is arranged to orient the flattened portion of each of said LEDs towards each other.

27. The opacity monitor of Claim 25 wherein each of said LEDs comprises a flange and wherein said optical diffuser comprises an inside surface, said predetermined distance comprising 12.5 mm between said LED flanges and said inside surface.

28. The opacity monitor of Claim 22 wherein said optical diffuser is supported inside a diffuser holder, said diffuser holder comprising a low-magnesium aluminum alloy.

29. The opacity monitor of Claim 28 wherein said optical diffuser is supported by inside surfaces of said diffuser holder, said inside surfaces being fine machined to provide increased light output from said light beams.

30. The opacity monitor of Claim 28 further comprising a glare shield coupled to said diffuser holder.

31. The opacity monitor of Claim 21 wherein said specific performance requirements comprise all of the requirements of ASTM D6216-98 and including opacity monitoring wherein:

said opacity monitor exhibits a change of less than or equal to 0.2 percent opacity when a supply voltage to said opacity monitor is increased or decreased from a nominal voltage by 10 percent;

said opacity monitor exhibits a change of less than or equal to 0.2 percent opacity for a 40°F (22°C) change in ambient temperature;

said opacity monitor exhibits a change of less than or equal to 0.2 percent opacity when exposed to ambient sunlight over the course of a day;

said opacity monitor exhibits a zero error of 0.2 percent or less;

said opacity monitor exhibits:

(a) a resolution of visual indication of 0.1 percent;

(b) a resolution of analog output of 0.1 percent;

(c) a resolution of digital output of 0.1 percent;

said opacity monitor exhibits a calibration error of less than or equal to 1 percent opacity;

said opacity monitor, when misaligned, displays an indication of that misalignment if a resulting change in opacity is 0.3 percent or greater; and

said opacity monitor exhibits a calibration device repeatability of 0.2 percent or less.

32. An opacity monitor for measuring the opacity of gases in an open path of gases, said opacity being defined as the fraction of transmitted light which is lost in transmission through the open path of gases, said opacity monitor comprising:

an optical transmitter having a light source that projects a homogeneous light beam across the open path of gases;

a reflector for reflecting a portion of said projected homogeneous light beam back towards said optical transmitter through said open path gas of gases;

an analyzer for detecting said portion of said projected homogeneous light beam and calculating the opacity of said gases; and

wherein said optical monitor detects opacities less than 10 percent while operating within specific performance requirements.

33. The opacity monitor of Claim 32 wherein said light source comprises:

a plurality of light emitting diodes (LEDs) arranged at a predetermined angular orientation with respect to each other and emitting respective light beams therefrom; and

an optical diffuser positioned at a predetermined distance from said plurality of LEDs for mixing and reflecting said respective light beams to form said homogeneous light beam.

34. The light source of Claim 33 wherein said plurality of LEDs comprises three LEDs.

35. The opacity monitor of Claim 34 wherein said predetermined angular orientation comprises arranging said LEDs to be oriented 120° with respect to each other.

36. The light source of Claim 35 wherein each of said LEDs comprises a pair of leads and wherein said light source further comprises:

an LED holder having three holes positioned 120° with respect to each other;

a clamp member having holes for each one of said leads; and

wherein said LED holder and said clamp member couple together to maintain said LEDs in said predetermined angular orientation.

37. The light source of Claim 36 wherein each of said LEDs comprises a flattened portion and wherein said clamp member is arranged to orient the flattened portion of each of said LEDs towards each other.

38. The opacity monitor of Claim 36 wherein each of said LEDs comprises a flange and wherein said optical diffuser comprises an inside surface, said predetermined distance comprising 12.5 mm between said LED flanges and said inside surface.

39. The opacity monitor of Claim 33 wherein said optical diffuser is supported inside a diffuser holder, said diffuser holder comprising a low-magnesium aluminum alloy.

40. The opacity monitor of Claim 39 wherein said optical diffuser is supported by inside surfaces of said diffuser holder, said inside surfaces being fine machined to provide increased light output from said light beams.

41. The opacity monitor of Claim 39 further comprising a glare shield coupled to said diffuser holder.

42. The opacity monitor of Claim 32 wherein said specific performance requirements comprise all of the requirements of ASTM D6216-98 and including opacity monitoring wherein:

said opacity monitor exhibits a change of less than or equal to 0.2 percent opacity when a supply voltage to said opacity monitor is increased or decreased from a nominal voltage by 10 percent;

said opacity monitor exhibits a change of less than or equal to 0.2 percent opacity for a 40°F (22°C) change in ambient temperature;

said opacity monitor exhibits a change of less than or equal to 0.2 percent opacity when exposed to ambient sunlight over the course of a day;

said opacity monitor exhibits a zero error of 0.2 percent or less;

said opacity monitor exhibits:

(a) a resolution of visual indication of 0.1 percent;

(b) a resolution of analog output of 0.1 percent;

(c) a resolution of digital output of 0.1 percent;

said opacity monitor exhibits a calibration error of less than or equal to 1 percent opacity;

said opacity monitor, when misaligned, displays an indication of that misalignment if a resulting change in opacity is 0.3 percent or greater; and

said opacity monitor exhibits a calibration device repeatability of 0.2 percent or less.

43. A method for reducing the variation in light intensity across a beam of light projected from a light source used in an opacity monitor, said method comprising the steps of:

(a) providing a plurality of light emitting diodes (LEDs), each having a respective optical axis and each emitting respective light beams;

(b) arranging said plurality of LEDs at a predetermined angular orientation with respect to each other and aligning each of said optical axes to be parallel to each other; and

(c) positioning an optical diffuser at a predetermined distance away from said plurality of LEDs for mixing and reflecting said respective light beams to form said beam of light having a reduced variation in light intensity.

44. The method of Claim 43 wherein said step of providing a plurality of LEDs comprises providing three LEDs.

45. The method of Claim 44 wherein said step of arranging said plurality of LEDs at a predetermined angular orientation comprises arranging said LEDs to be oriented 120° with respect to each other.

46.The method of Claim 44 wherein said step of positioning an optical diffuser at a predetermined distance comprises positioning an inside surface of said optical diffuser 12.5 mm from a flange of each of said LEDs.

47. A method for reducing the variation in light intensity across a beam of light projected from a light source used in an opacity monitor, said method comprising the steps of:

(a) providing a plurality of light emitting diodes (LEDs), each having a respective optical axis and each having symmetrical and asymmetrical inhomogeneities in respective light beams emanating from each LED;

(b) minimizing said symmetrical and asymmetrical inhomogeneities in said respective light beams by:

(1) orienting said plurality of LEDs within in a common plane; and

(2) positioning an optical diffuser at a predetermined distance away from said plurality of LEDs to mix and reflect said respective light beams to form said beam of light having said reduced variation in light intensity across said beam of light.

48. The method of Claim 47 wherein said step of orienting said plurality of LEDs within a common plane comprises arranging said plurality of LEDs at a predetermined angular orientation with respect to each other and aligning each of said optical axes to be parallel to each other.

49. The method of Claim 48 wherein said step of providing a plurality of LEDs comprises providing three LEDs.

50. The method of Claim 49 wherein said step of arranging said plurality of LEDs at a predetermined angular orientation comprises orienting said three LEDs 120° with respect to each other.

51. The method of Claim 50 wherein said step of positioning an optical diffuser at a predetermined distance away from said plurality of LEDs comprises positioning an inside surface of said optical 12.5 mm from flanges of said LEDs.

52. A method for measuring the opacity of gases in an open path of gases, said opacity being defined as the fraction of transmitted light which is lost in transmission through the open path of gases, said method comprising the steps of:

(a) projecting a light beam across the open path of gases using a light source that reduces the variation in light intensity across said projected beam;

(b) reflecting a portion of said projected light beam;

(c) detecting and analyzing said portion of said portion of said projected light beam;

(d) detecting opacities less than 10 percent while operating within specific performance requirements.

53. The method of Claim 52 wherein said step of projecting a light beam across the open path of gases comprises:

(a) providing a plurality of light emitting diodes (LEDs), each having a respective optical axis and each emitting respective light beams;

(b) arranging said plurality of LEDs at a predetermined angular orientation with respect to each other and aligning each of said optical axes to be parallel to each other; and

(c) positioning an optical diffuser at a predetermined distance away from said plurality of LEDs for mixing and reflecting said respective light beams to form said beam of light having a reduced variation in light intensity.

54. The method of Claim 53 wherein said step of providing a plurality of LEDs comprises providing three LEDs.

55. The method of Claim 54 wherein said step of arranging said plurality of LEDs at a predetermined angular orientation comprises arranging said LEDs to be oriented 120° with respect to each other.

56. The method of Claim 54 wherein said step of positioning an optical diffuser at a predetermined distance comprises positioning an inside surface of said optical diffuser 12.5 mm from a flange of each of said LEDs.

57. The method of Claim 52 wherein said step of operating within specific performance requirements comprises utilizing an opacity monitor operating in accordance with all of the requirements of ASTM D6216-98 and including opacity monitoring wherein:

said opacity monitor exhibits a change of less than or equal to 0.2 percent opacity when a supply voltage to said opacity monitor is increased or decreased from a nominal voltage by 10 percent;

said opacity monitor exhibits a change of less than or equal to 0.2 percent opacity for a 40°F (22°C) change in ambient temperature;

said opacity monitor exhibits a change of less than or equal to 0.2 percent opacity when exposed to ambient sunlight over the course of a day;

said opacity monitor exhibits a zero error of 0.2 percent or less;

said opacity monitor exhibits:

(a) a resolution of visual indication of 0.1 percent;

(b) a resolution of analog output of 0.1 percent;

(c) a resolution of digital output of 0.1 percent;

said opacity monitor exhibits a calibration error of less than or equal to 1 percent opacity;

said opacity monitor, when misaligned, displays an indication of that misalignment if a resulting change in opacity is 0.3 percent or greater; and

said opacity monitor exhibits a calibration device repeatability of 0.2 percent or less.